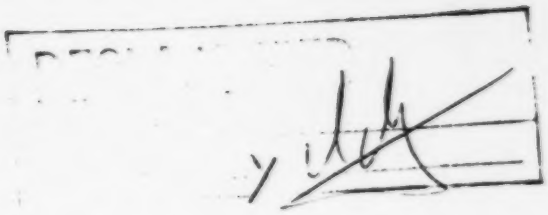

UTILIZATION OF WASTE FROM FLUIDIZED-BED COMBUSTION OPERATION AS A CEMENTITIOUS MATERIAL. PART III

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INTRODUCTION

The present report is part of an Agreement between CANMET/EMR, Ottawa and L.E. Shaw, Halifax, dealing with a study on the evaluation of waste products from fluidized-bed combustion operations and their use in blends with Lingan fly ash as a cementitious material for low strength concretes without addition of portland cement. The performance of nine concretes incorporating these blends was previously reported (1) and, as a consequence of its evaluation, it was recommended to reproduce a concrete mixture designated as CHT6, to determine long term compressive and flexural strengths and expansion under moist curing conditions. The continuation of the measurements of long-term compressive strength and expansion in moist curing conditions of concretes from mixtures designated as CHT8 and CHT9 was also recommended. Independently of these tests, mortars were made to explore the possibility of eliminating the expansion due to the hydration of the $CaSO_4$ present in the Chatham ash (2) by prehydrating the ash with two different solutions of barium salts prior to mixing the mortars.

Materials

Having exhausted the stock of Chatham silo ashes No. 54 and No. 56 used in previous tests, Chatham silo ash No. 74 was used for the mortar mixtures made with the prehydrated Chatham ash and for the concrete mixture CHT6R. The mean density and chemical composition of the Chatham ash No. 74 was similar to that of ash No. 54, although the fineness and total carbon content of ash No. 74 was significantly higher than that of ash No. 54 (2).

Mortars Incorporating Prehydrated Chatham Ash

One mortar mixture was prepared with Chatham ash No. 74 prehydrated with 18 percent (by weight of ash) of a solution of barium acetate and another mortar mixture was prepared with the

same ash prehydrated with 18 percent (by weight of ash) of a solution of barium chloride. The mortars were made 24 hours after prehydration. The amounts of the barium salts used to prepare the solutions were 50 percent of the amounts required to neutralize the $CaSO_4$ in the Chatham ash, according to the following reactions:

$$CaSO_4 + Ba(CH_3.COO)_2 \text{ -----> } BaSO_4 + Ca(CH_3.COO)_2$$
$$CaSO_4 + BaCl_2 \text{ -----> } BaSO_4 + CaCl2$$

For comparison, a mortar mixture incorporating a non-prehydrated Chatham ash and a mortar mixture incorporating Chatham ash prehydrated with 18 percent water by weight of ash were also made.

As previously reported, the mortars were prepared according to ASTM Test C 109, with a water-to-binder ratio necessary to give a flow of 110 ± 5 percent (2). The proportions Lingan fly ash and Chatham ash were such that the ratio of weight of Lingan fly ash to the equivalent weight of CaO in the Chatham ash was 1.41 (2). The length change of 25 x 25 x 305-mm prisms measured as a percentage of the initial length and the compressive strength determined in 51 x 51-mm mortar cubes are reported in Table 1. All measurements were made at various ages up to 120 days.

Proportioning of the Concrete Mixture

The concrete mixture CHT6R was proportioned similarly to the concrete mixture CHT6 as previously reported (1). However, additional water was required in mixture CHT6R to obtain a slump similar to that of concrete from mixture CHT6. The proportions and properties of the fresh concrete from mixture CHT6R as well as those of concretes from mixtures CHT8 and CHT9 previously made, are shown in Table 2.

Mixing, Casting and Curing of the Concrete Specimens

The details of the mixing, casting and curing of the concrete specimens of mixtures CHT8 and CHT9 have already been reported (1). For concrete from mixture CHT6R, six 76 x 102 x 387-mm prisms were cast and cured in three different conditions, as described in Table 3. Measurements of changes in length and weight, as well as flexural strength, were made at various ages up to 84 days. Nine 102 x 203-mm cylinders were cast and cured for 24 h under wet burlap and subsequently moist cured at 100% R.H. for compressive strength testing at 7, 28 and 84 days.

TEST RESULTS

Mortars

As shown in Table 1, the prisms incorporating unhydrated Chatham ash present the least expansion and the highest compressive strengths at all ages up to 120 days. The prehydration of the ash with barium acetate solution seems to have a negative effect, resulting in mortars with 4.39 and 7.72 percent expansion at 14 and 28 days, respectively. The prisms disintegrated before 120 days of moist curing. Prehydration of the Chatham ash with barium chloride solution resulted in mortars showing slightly lower expansion and significantly higher compressive strength at 120 days than the mortars incorporating Chatham ash prehydrated with water (Table 1).

Concretes

a) Length and Weight Changes

The concrete prisms from mixture CHT6R cured at 60°C for 24 hours prior to moist curing show lower expansion and weight change compared to the moist cured prisms (Table 3). Moist curing for 3 days followed by air-drying conditions cause shrinkage and weight loss as shown by measurements made up to 84 days (Table 3). In the concretes from mixtures CHT8 and CHT9, measurements performed on the prisms up to 120 days indicate that

curing at 60°C for one day followed by moist curing at 100% R.H. results in substantial reduction of expansion and weight increase with time compared to the moist cured specimens (Table 4). The addition of 10 percent portland cement by weight with respect to the binder in mixture CHT9 seems to reduce further the expansion of concrete prisms cured at 60°C for one day and subsequently moist cured, especially at 84 and 120 days (Table 4). At 120 days, the expansion of concrete prisms with and without addition of portland cement is the same when the prisms are moist cured.

b) Compressive and Flexural Strengths

The flexural strength of concrete prisms from mixture CHT6R is higher when the specimens are moist cured at 23 ± 1.7°C and 100% R.H. for 3 days and subsequently air dried at 23 ± 1.7°C and 50% R.H. The compressive strengths of concrete from mixture CHT6R are lower than those of concrete from mixture CHT6 at all ages, probably due to the higher water-to-cement ratio used in mixture CHT6R to attain a slump similar to that measured in mixture CHT6 (1).

Compressive strengths of moist-cured cylinders of concretes from mixtures CHT8 and CHT9 were not determined. The compressive strength values of concrete cylinders from the same mixtures cured at 60°C for 24 hours and subsequently moist cured, are slightly higher at 3 days than at 7 days. There is no significant increase of strength after 28 days of curing in both concretes from mixtures CHT8 and CHT9.

CONCLUDING REMARKS

1. Heat curing the concrete specimens at 60°C for 24 hours and subsequent moist curing significantly decrease the rate of expansion as compared to the moist curing alone.
2. The addition of 10% by weight of portland cement with respect to the binder in the concrete from mixture CHT9 results in slightly higher compressive strengths in

specimens cured for 24 hours at 60°C prior to moist curing as compared to the concrete mixture without portland cement. The expansion of concrete prisms from mixture CHT8 is lower in the specimens cured at 60°C for 24 hours than in the moist-cured specimens. The long-term expansion of the moist-cured specimens is the same in the concretes with and without addition of portland cement.

3. Moist curing for three days followed by air drying results in slight shrinkage and weight loss in the concrete specimens, comparable to that observed in portland cement concrete. However, this observation has little practical significance to field applications.

RECOMMENDATIONS

Low-strength concrete made with blends of waste from fluidized-bed combustion operations and Lingan fly ash attain unacceptable expansion levels after 30 days of moist curing. Although curing at 60°C for 24 hours followed by moist curing delays the progress of the expansion process, the procedure would be uneconomical and ultimately will not halt the map cracking and final disintegration of the concrete.

It is recommended to discontinue the study at the present time. If other means are found to mask the expansion due to the conversion of the $CaSO_4$ to $CaSO_4.2H_2O$, further investigation would be justified.

REFERENCES

1. Douglas, E., Painter, K. and Malhotra, V.M. "Utilization of waste from fluidized-bed combustion operation as a cementitious material. Part II", MSL Report 89-14 (CR)

2. Douglas, E. and Painter, K. "Utilization of waste from fluidized-bed combustion operation as a cementitious material. Part I", MSL Report 89-2 (CR)

Table 1 - Length Change and Compressive Strength in Mortars

Sample No.	Preparation and Curing Conditions*	Length Changes, %			Compressive Strength, MPa**		
		Age, Days			Age, Days		
		14	28	120	7	28	120
74-1	Not Prehydrated	1.02	1.61	3.16	4.3	8.7	19.4
74-2	Prehydrated with Water	1.19	2.28	4.74	2.6	4.7	12.1
74-3	Prehydrated with Barium Acetate	4.39	7.72	disinte-grated	0.5	1.6	4.6
74-4	Prehydrated with Barium Chloride	1.65	3.79	4.25	1.7	5.0	18.1

* Curing conditions: all specimens were moist cured after casting
** Average of three test results

Table 2 - Proportions and Properties of Fresh Concretes

Mixture No.	Proportions of Fresh Concrete, kg/m^3						Properties of Fresh Concrete		
	Fine Agg.*	Coarse Agg.**	Water	Cement***	Lignan Fly Ash	Chatham Ash****	Unit Weight kg/m^3	Temperature C	Slump mm
CHT6R	437	743	306	--	148	532 (74)	2166	26	100
CHT8	475	812	302	--	162	587 (54)	2172	27	75
CHT9	399	686	308	71	153	153 (54)	2172	28.5	130

* Natural Sand
** Limestone
*** CSA Type 10 Portland Cement
**** Number in Brackets Represents Chatham Ash Source Used

Table 3 - Physical and Mechanical Properties of Hardened Concrete CHT6R

Prism No.	Curing Procedure	Changes in Length Measurements, %		Changes in Weight Measurements, Kg		Flexural Strength at 84 days, MPa
		Age		Age		
		28 d	84 d	28 d	84 d	
1	Accelerated-cured at 60C for 24-hours, followed by moist curing at 23C ± 1.7 and 100% R.H.	0.30	0.91	0.077	0.255	1.4
2		0.26	0.79	0.061	0.242	
3	Moist-cured at 23C ± 1.7 and 100% R.H.	0.59	1.77	0.107	0.302	1.2
4		0.74	1.62	0.103	0.291	
5	Moist-cured for 3-days at 23C ± 1.7 and 100% R.H. followed by lab drying	-0.008	-0.02	-0.082	-0.249	2.6
6		-0.014	-0.03	-0.018	-0.041	

Density Kg/m^3*	Compressive Strength, MPa**		
	Age		
	7 d	28 d	84 d
2.160	2.2	2.8	3.4

* Average of nine test results
** Average of three test results. Specimens moist cured

Table 4 - Physical and Mechanical Properties of Hardened Concrete CHT8 and CHT9

Id.	Curing Conditions	Density Kg/m^3*	Changes in Length Measurements, %					Changes in Weight, Kg					Compressive Strength, MPa**			
			Age, days					Age, days					Age, days			
			35	42	54	84	120	35	42	54	84	120	3	7	28	91
CHT8	Heated at 60C for 24-hours, then moist cured	2.143	0.03	0.07	0.16	0.33	1.08	0.070	0.102	0.226	0.253	0.316	19.2	18.1	19.9	20.1
	Continuously moist cured		0.14	0.35	0.63	1.10	2.16	0.130	0.158	0.227	0.278	0.418	N/A	N/A	N/A	N/A
CHT9	Heated at 60C for 24-hours, then moist cured	2.151	0.03	0.06	0.11	0.19	0.62	0.075	0.105	0.219	0.241	0.282	23.6	20.8	25.7	25.5
	Continuously moist cured		0.06	0.15	0.35	0.75	2.15	0.065	0.103	0.231	0.277	0.395	N/A	N/A	N/A	N/A

* Average of measurements in eight cylinders
** Average of three test results